

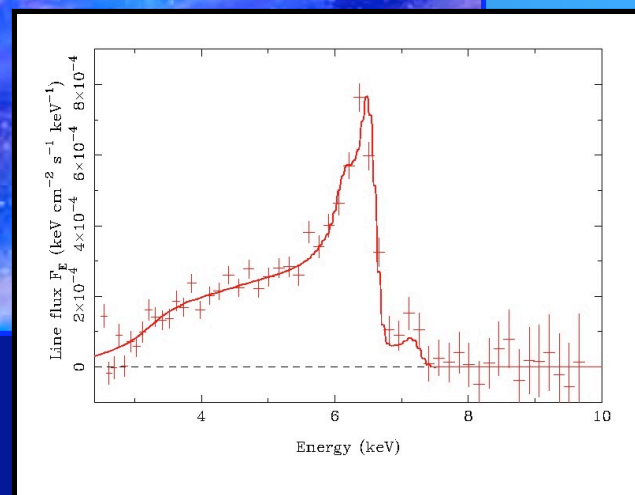
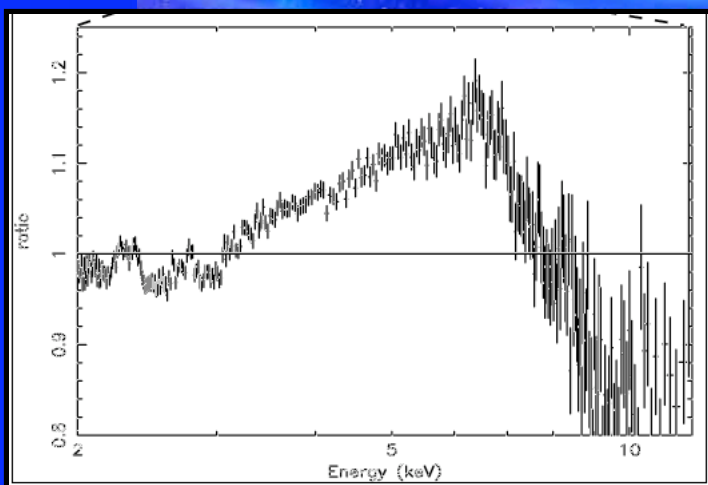
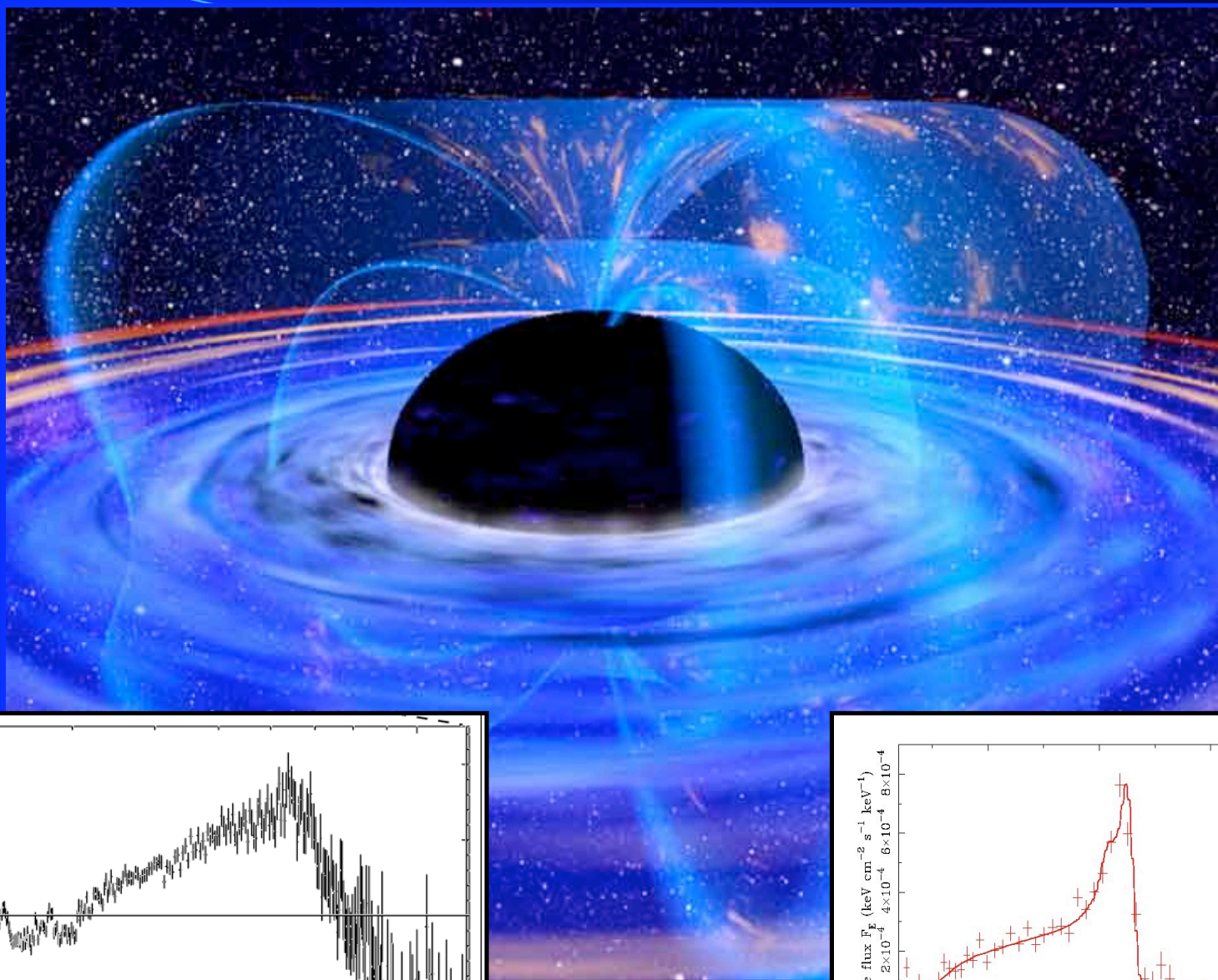
Testing strong gravity with high throughput X- ray spectroscopy

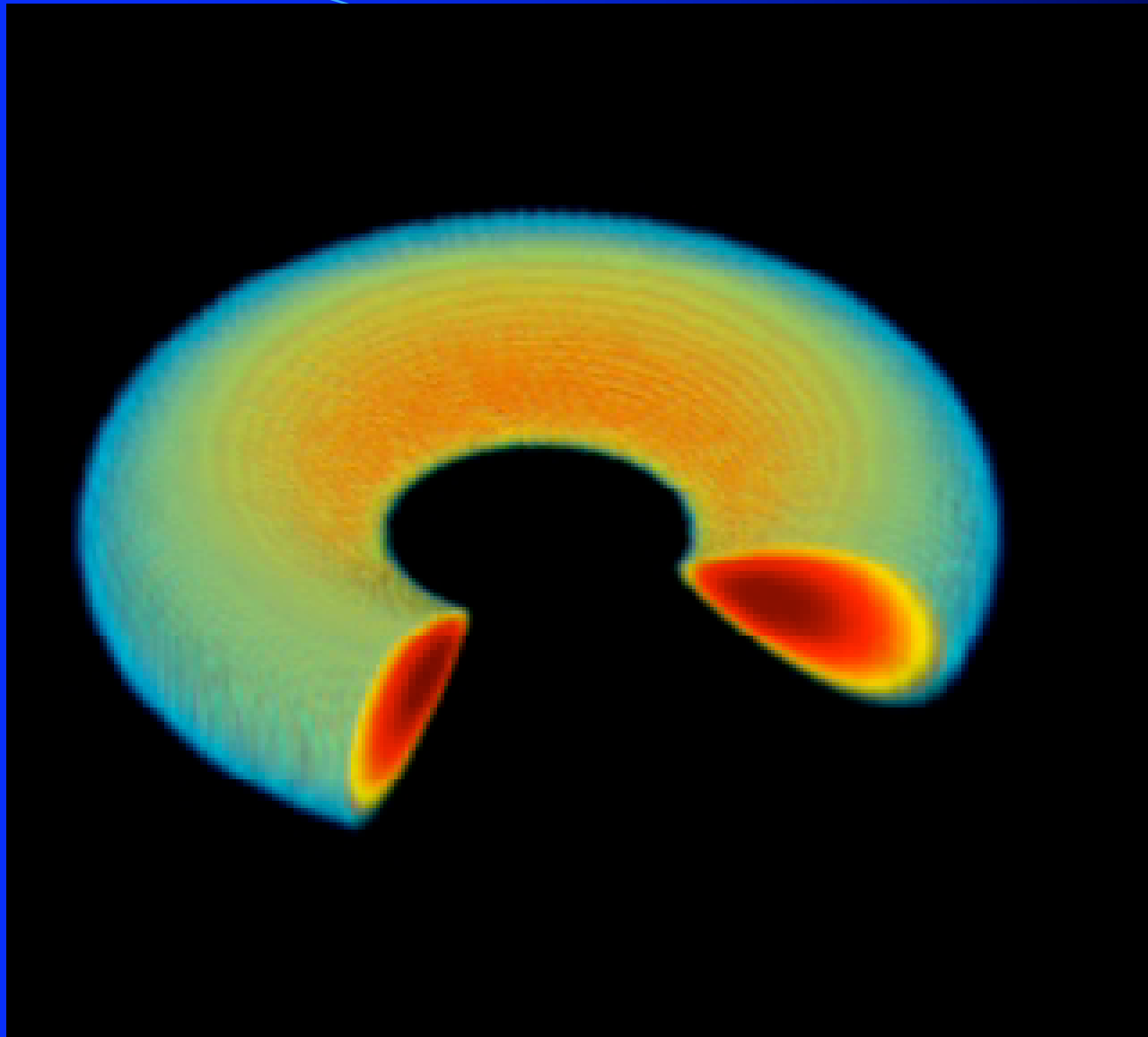
Chris Reynolds

Department of Astronomy
University of Maryland

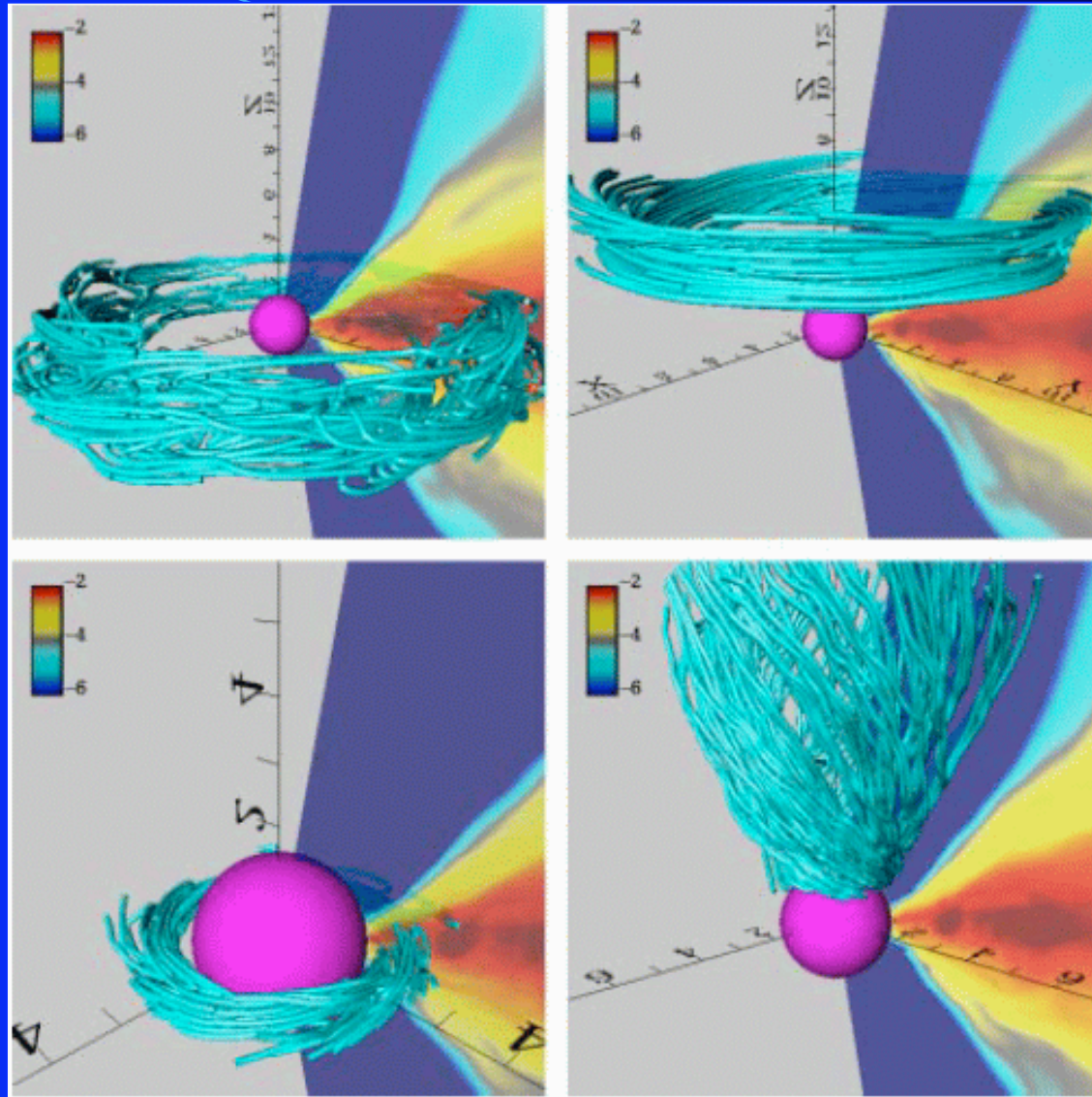


Constellation-X Black Hole Workshop
GSFC, 17-18th September 2004



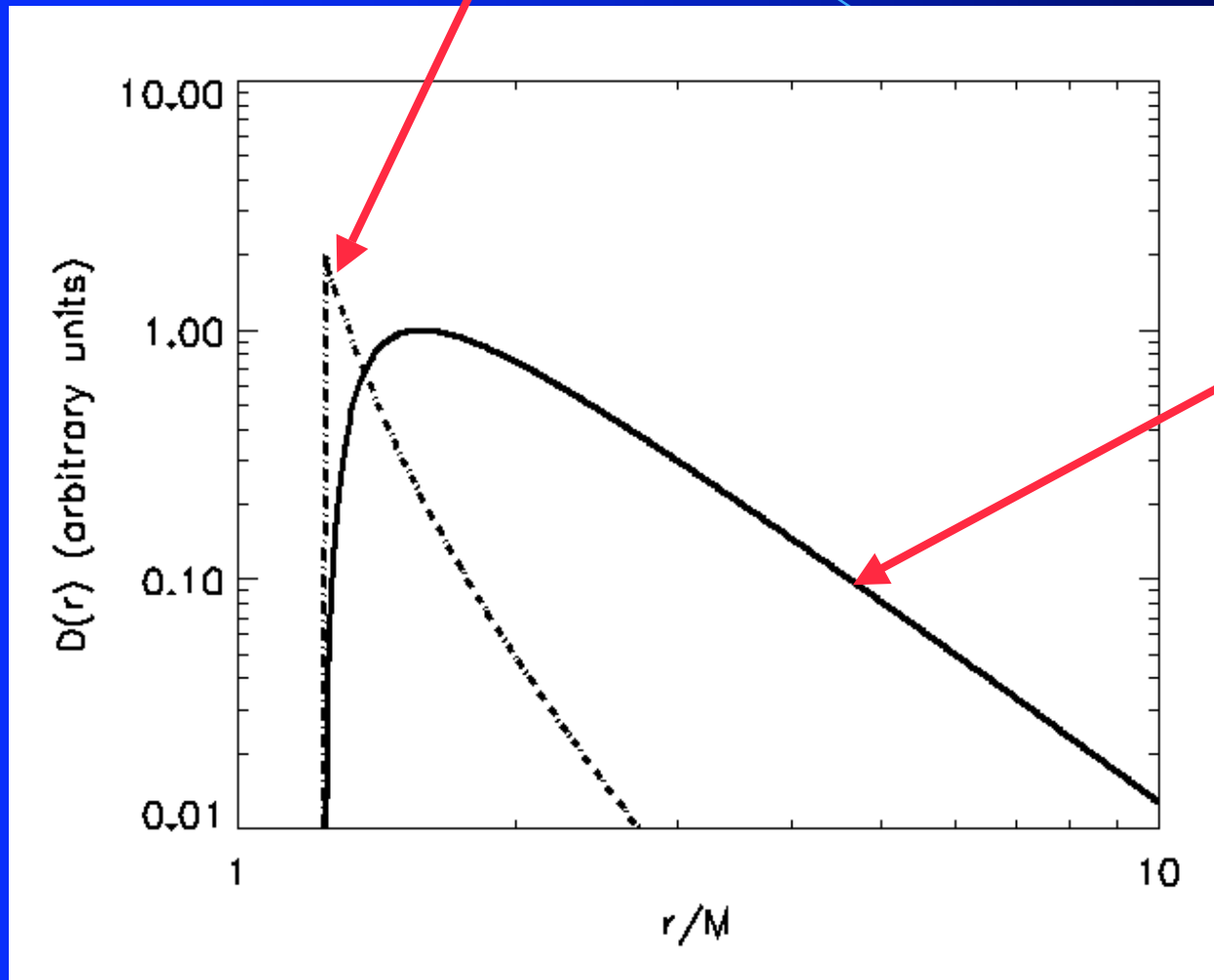


**MHD accretion disk simulation
(Hawley & Krolik 2001)**

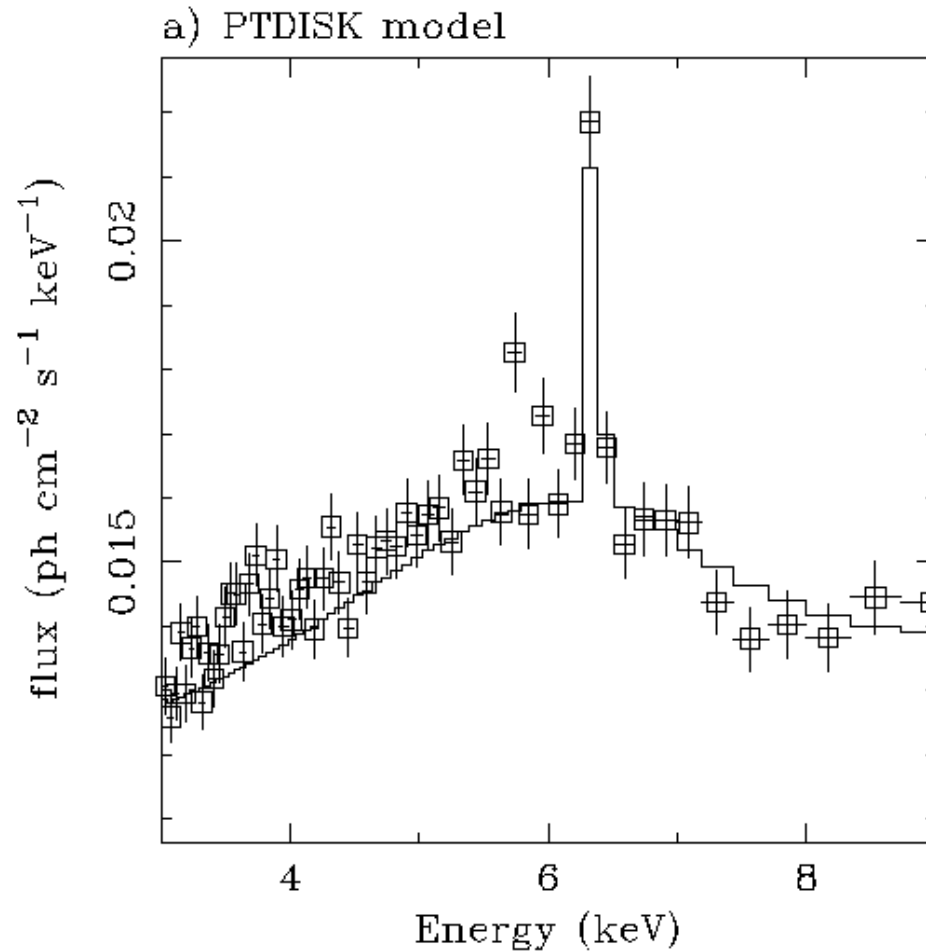


GR-MHD simulations by Hirose, Hawley & Krolik (2003)

**Dissipation of work done
by torque at radius of
marginal stability**



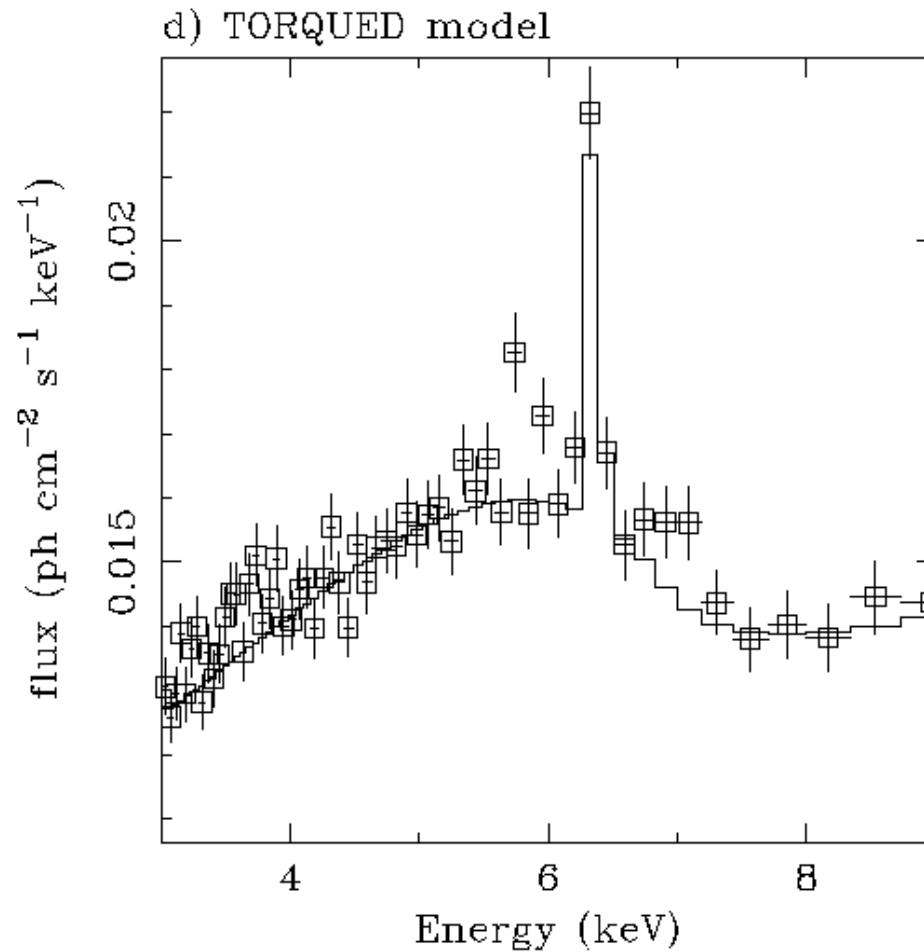
**Accretion
Luminosity**



**CSR et al
(2004)**

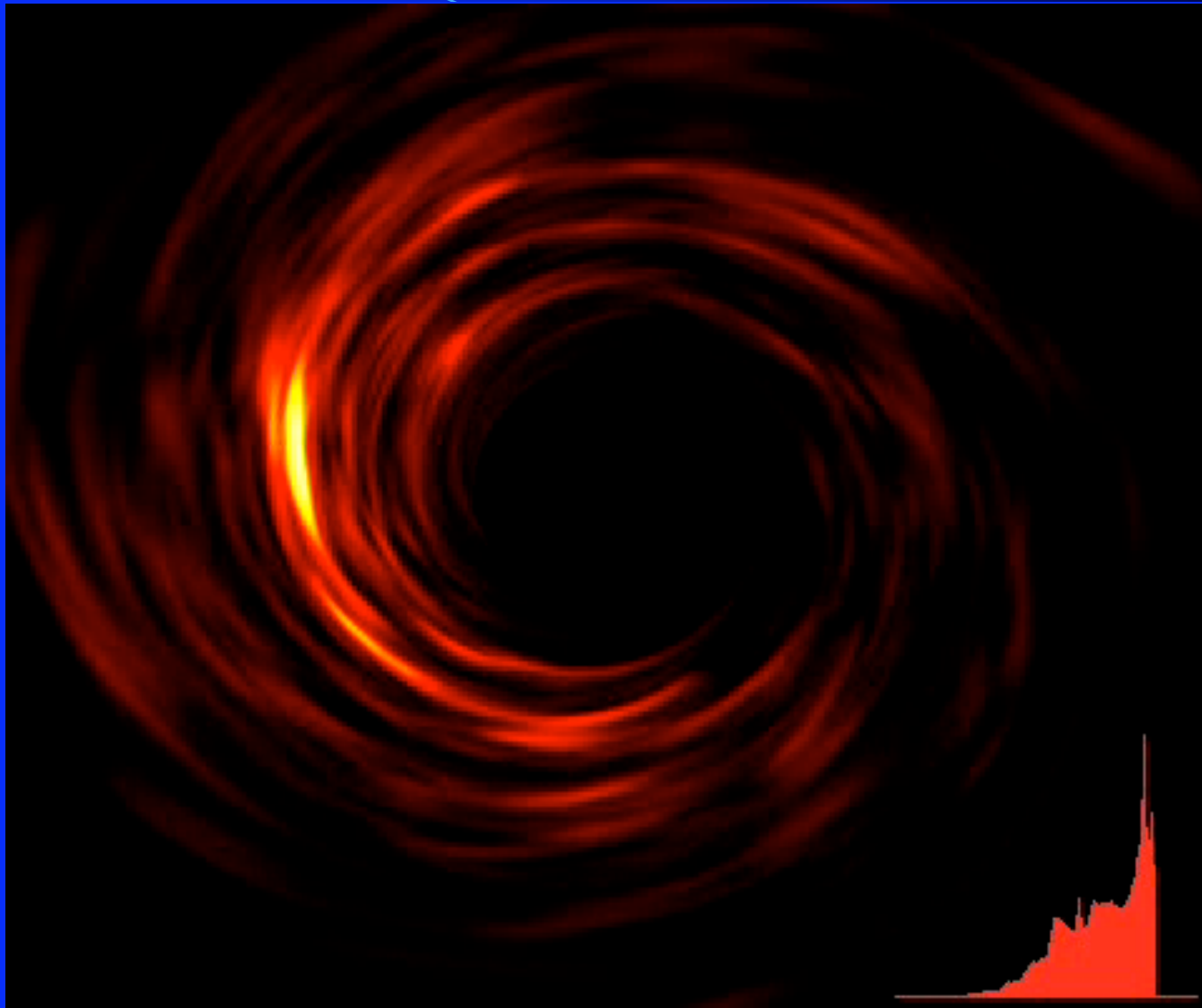
MCG-6-30-15

Fit with a Novikov-Thorne/Page-Thorne disk

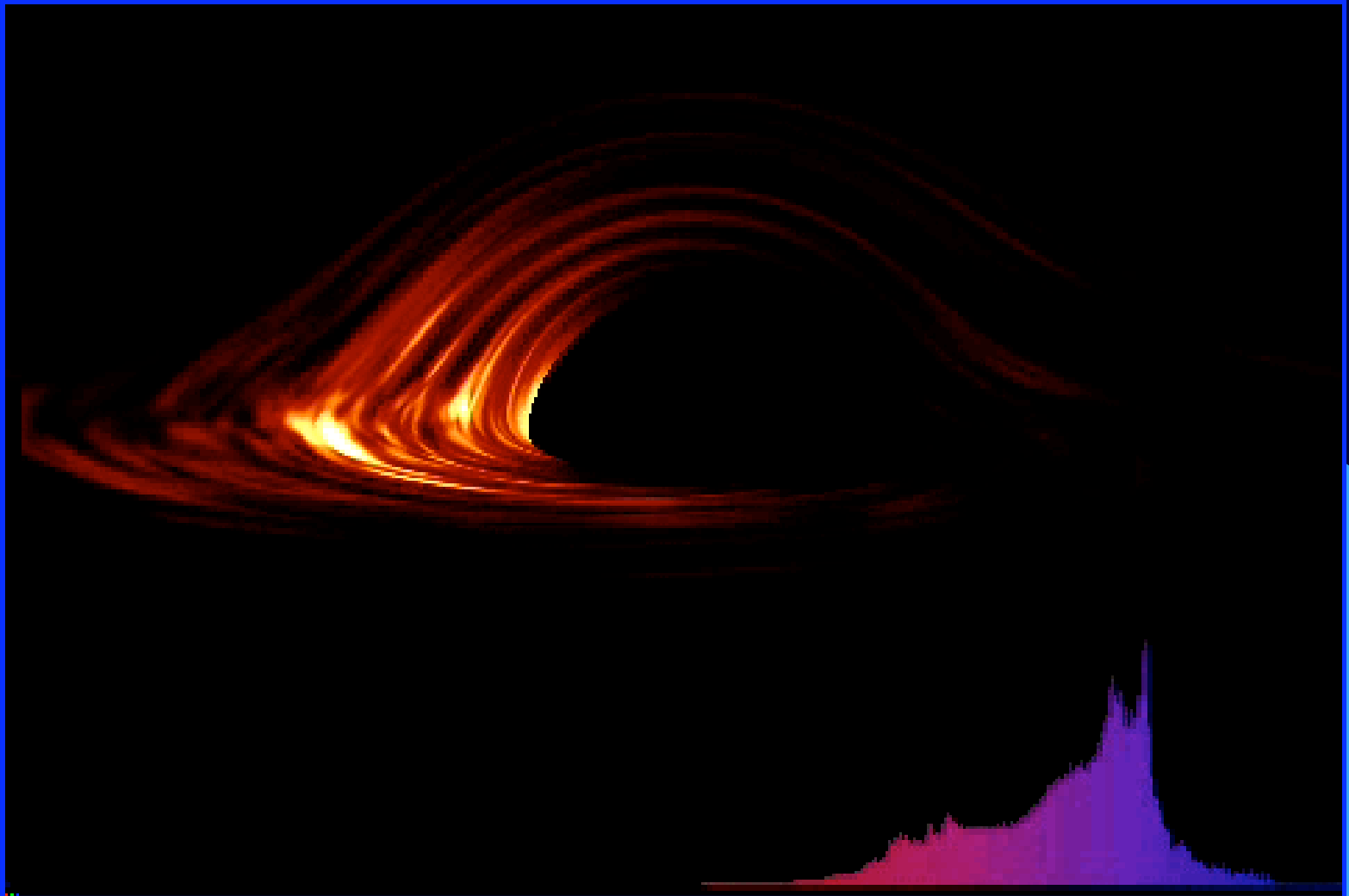


CSR et al
(2004)

Fit with a Agol & Krolik torqued disk
(need “infinite efficiency case”)

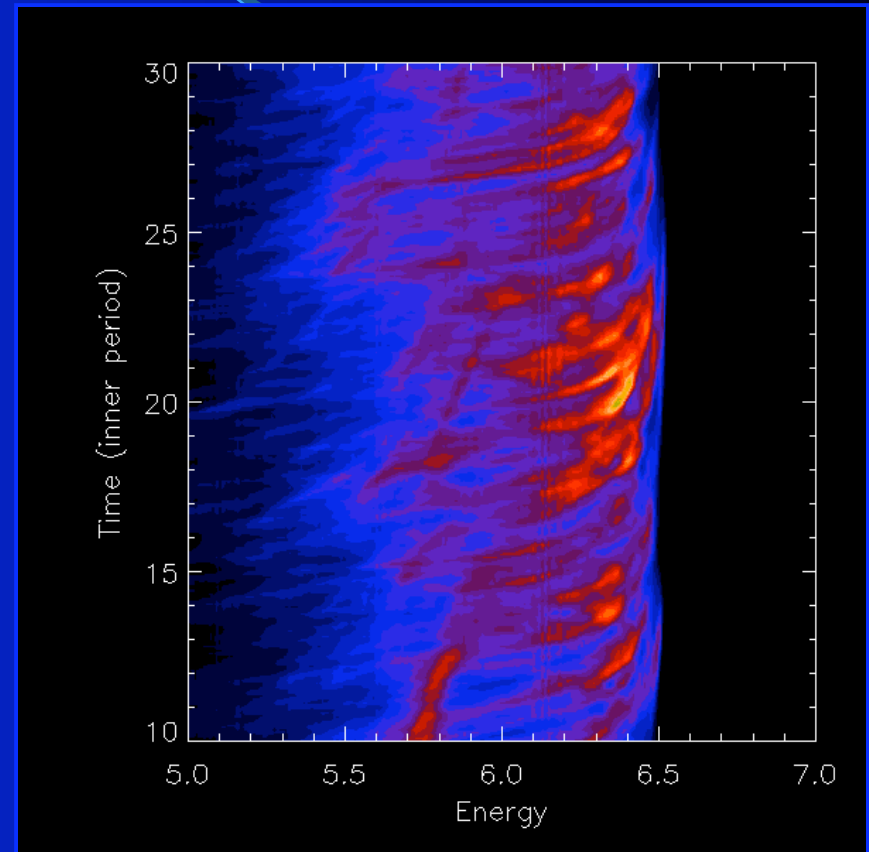


Armitage & CSR (2003)



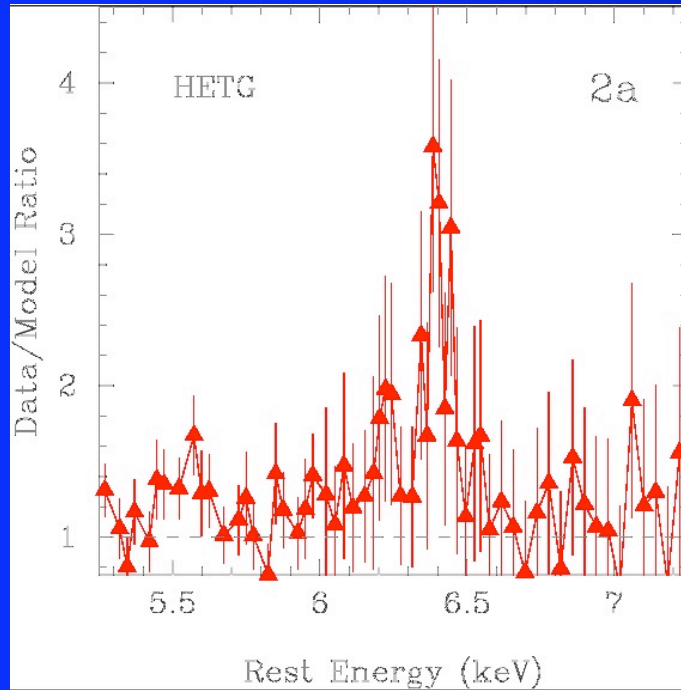
Iron line variability

- λ Con-X will allow detailed study of line variability
- λ See effects of non-axisymmetric structure orbiting in disk
 - Follow dynamics of individual “blobs” in disk
 - Quantitative test of orbital dynamics in strong gravity regime

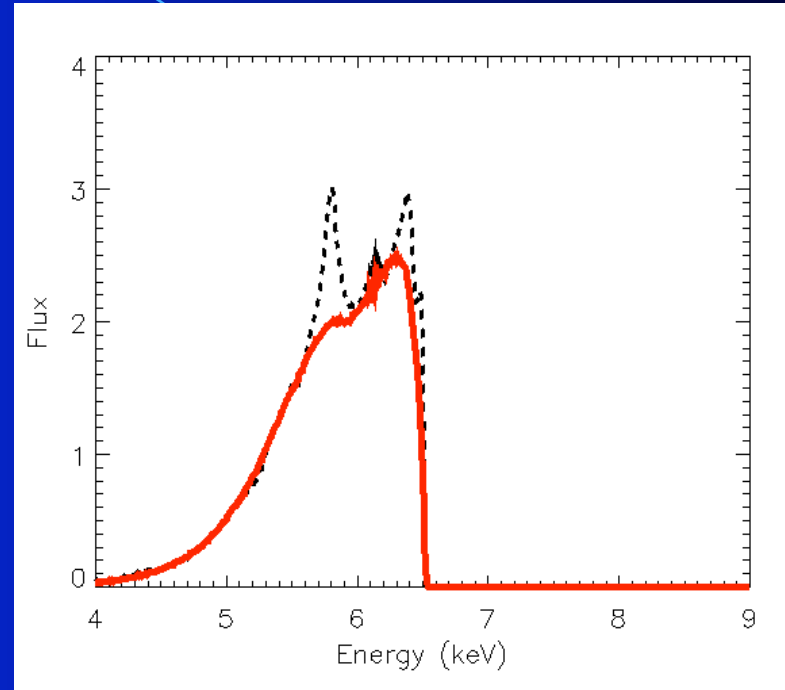


Armitage & CSR (2003)

Non-axisymmetric structure may have been seen already...



Chandra-HETG data on NGC3516
(Turner et al. 2002)



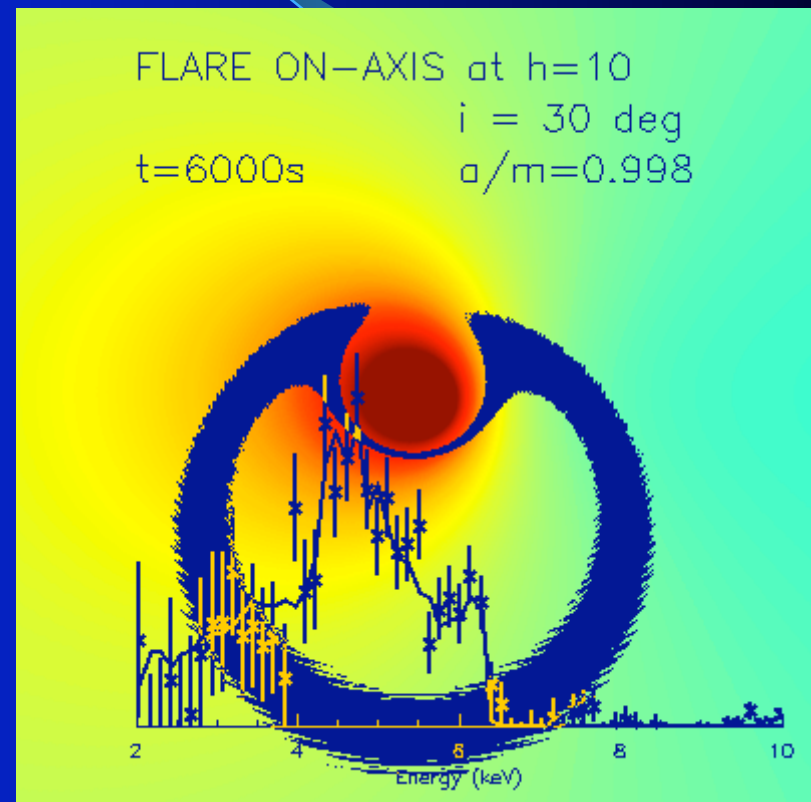
Simulation results for inclination
of 20 degs (summed over 2 full orbits)

A prime science target for Astro-E2

Relativistic iron line reverberation...

λ Reverberation

- X-ray source displays dramatic flares
- Flare produces “X-ray echo” that sweeps across accretion disk
- Iron line profile will change as echo sweeps across disk
- Needs high throughput spectroscopy – but likely within reach of Con-X



CSR et al. (1999)

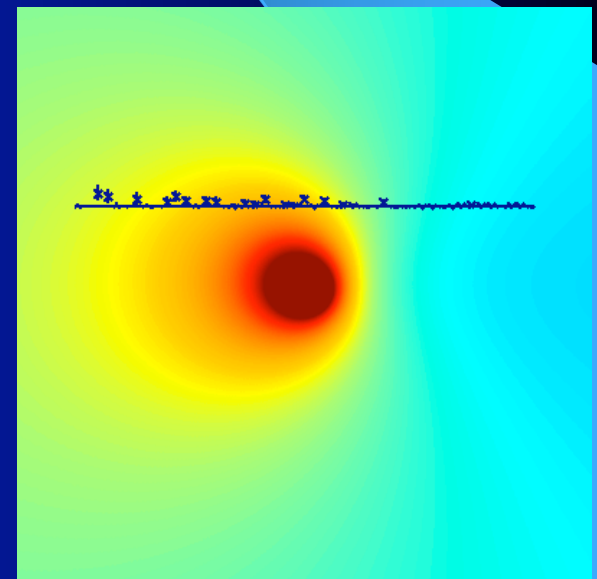
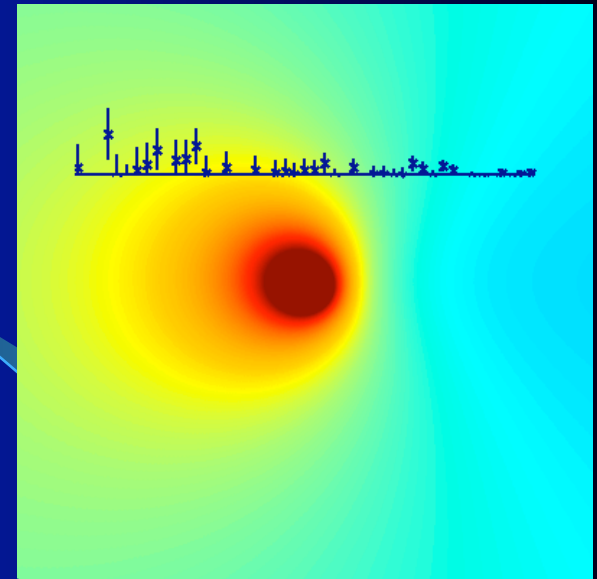
Young & CSR (2000)

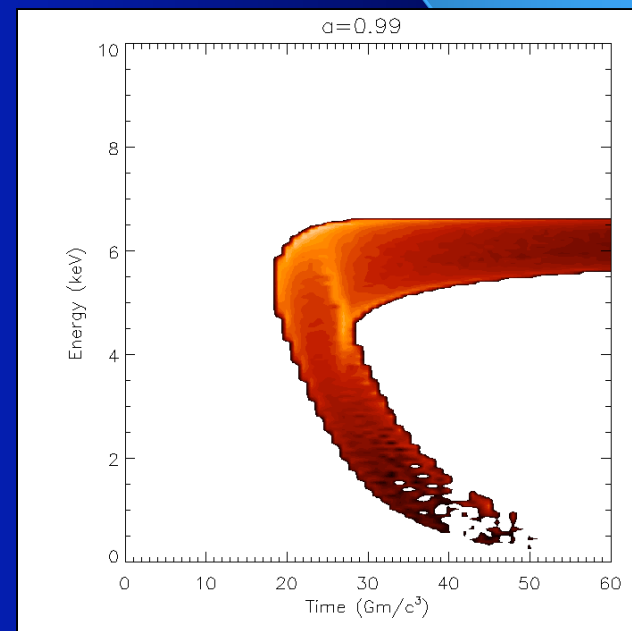
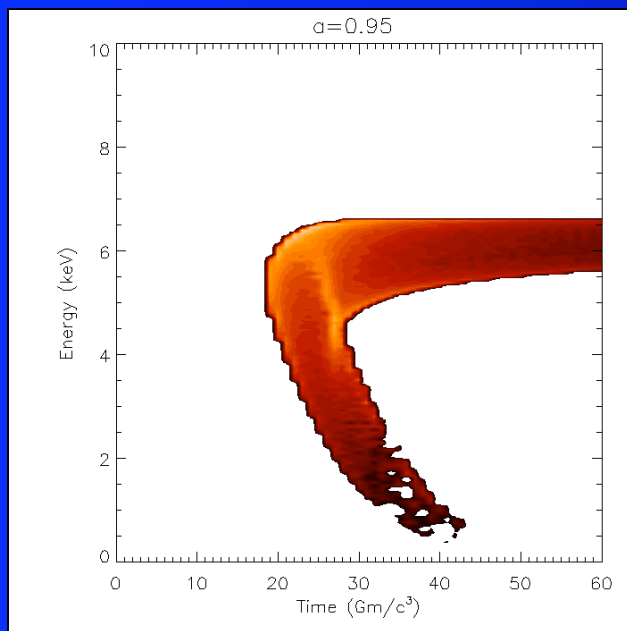
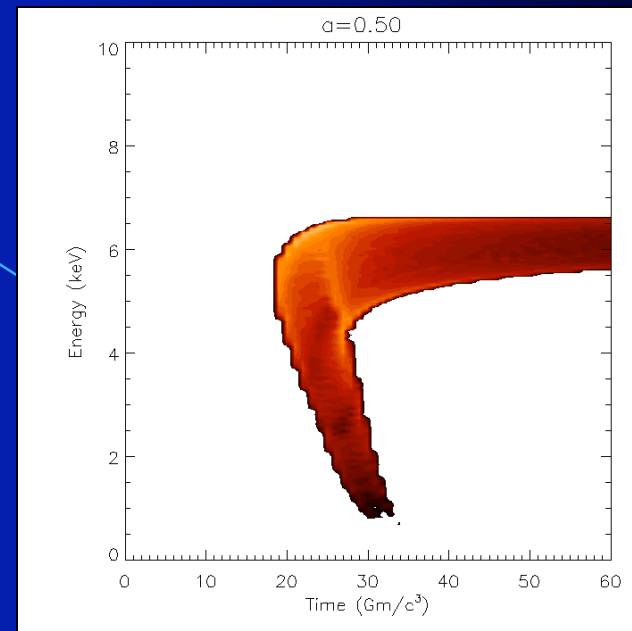
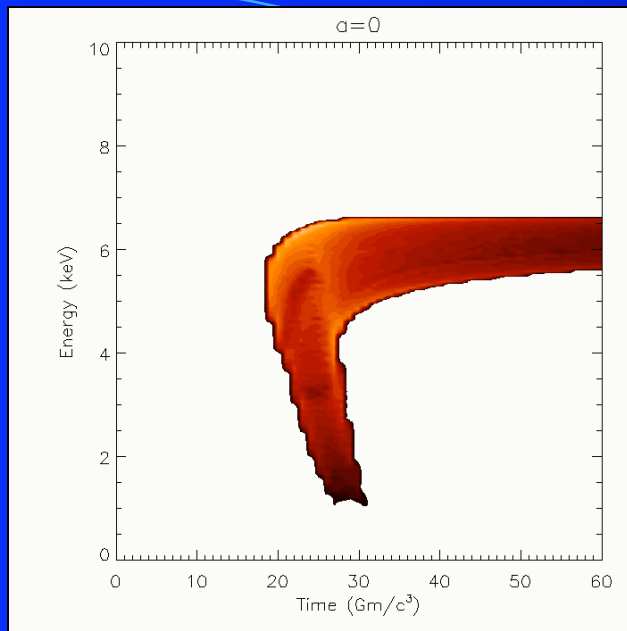
λ Sensitive probe of strong gravity

- Get inward and outward propagating X-ray echoes
- inward propagating echo is purely a relativistic effect
- Inward propagating echo gives red-bump on the iron line profile
- Precise properties of red-bump are probe the Kerr metric (and allow measurement of BH spin)

λ Side note... we already know that situation is not simple;

- Current data suggest complex ionization changes associated with variability
- Need hard X-ray capability of Con-X to deconvolve effects of disk ionization in a realistic spectrum.





Reynolds et al. (1999)

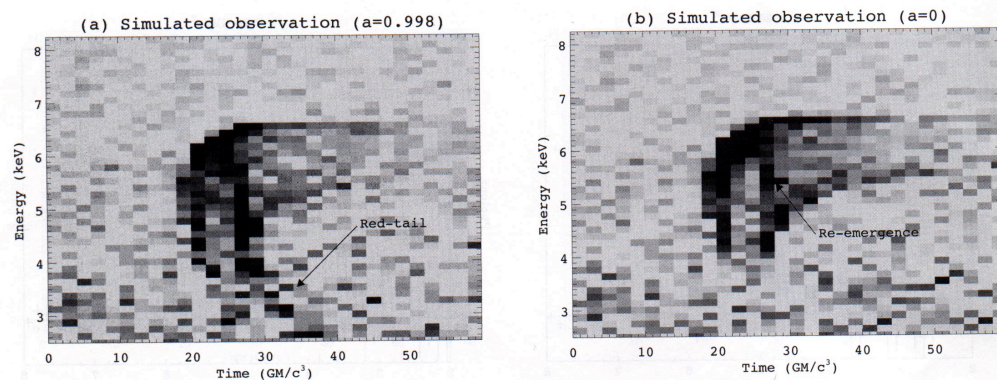


FIG. 4.—Simulated transfer function for (a) an extremal Kerr hole and (b) a Schwarzschild hole. In both cases, the flare has been placed on the symmetry axis at a height of $10GM/c^2$ above the disk plane, and an observer inclination of 30° has been assumed. The data have been rebinned to produce these figures with improved signal-to-noise ratio.

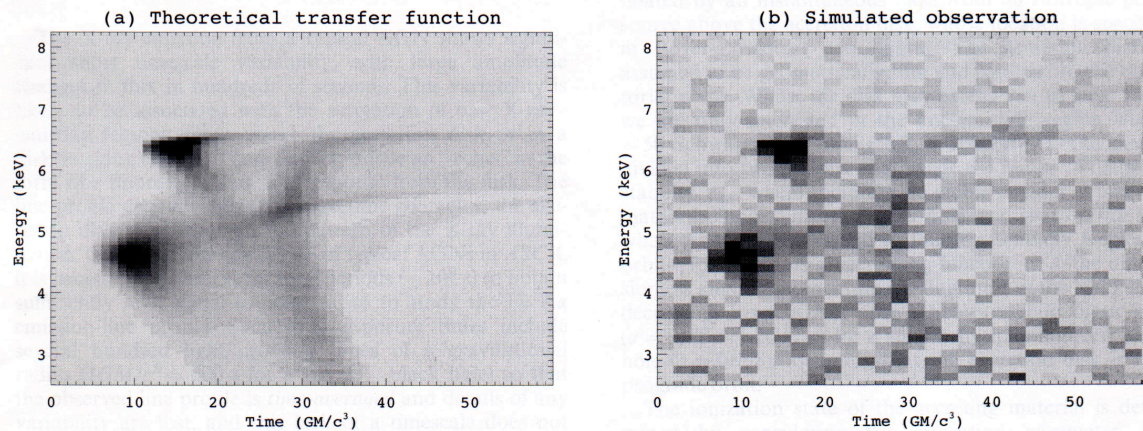


FIG. 7.—Panel a shows the theoretical line response to the two overlapping flares described in the text. Panel b shows the simulated line response as seen by *Constellation-X*. The individual transfer functions of the two flares can be discerned. The data have been rebinned to produce these figures with improved signal-to-noise ratio.

Constellation-X simulations

Conclusions

- λ **X-ray observations are already probing region in immediate vicinity of accreting stellar & supermassive black holes**
- λ X-ray astronomy is on the verge of realizing its ultimate promise (BHFP, Con-X, and BHI/MAXIM)
 - Probe of **BH growth** back to cosmic “dark ages”
 - Constraints on **strong field gravity**
 - Detailed understanding of **BH accretion**
 - Accessed through high-throughput spectroscopy (Con-X), and direct imaging (BHI)